2 Description

2.1 Scope of delivery and brief description of the "X-ray apparatus 42 kV," equipment
(Refer to Figure 1-5 on the folding page at the end of the book)

2.1.1 42 kV X-ray apparatus (554 90)

Apart from the basic apparatus (Figure 1), the scope of delivery of the 42 kV X-ray apparatus (554 90) comprises:

Slit diaphragm collimator Ⓐ, which is inserted in the beam outlet aperture and which permits stopping down of a slim bundle of X-rays with an aperture of approximately 0.5°.

Plug-on angular scale Ⓑ with 0.5 degree divisions 0°...60°.

Counter tube holder Ⓒ for the end-window counter (559 05 or 01) for securing to the retaining disk ㉗, coupled with the long pointer ⑮.

Shaft with sample holder Ⓓ for insertion into the hollow shaft of the goniometer mechanism; secured with a captive knurled screw ⑯; coupled to the short pointer ⑭; on the sample holder, securing attachments for the absorber holder (from 554 92) and for the rotating table ㉘ for placing monocrystals (554 77/78) and scattering elements Ⓛ, for instance.
In conjunction with a pulse-counting apparatus (e.g. rate meter, 575 52, with digital counter 575 50), the basic apparatus equipped with the slit diaphragm collimator Ⓐ, the angular scale Ⓑ, counter tube holder Ⓒ with end-window counter (559 05 or 01), sample holder Ⓓ and rotating table ㉘ forms a counter tube goniometer which can be swivelled with respect to the horizontal axis.

Experimenting rail Ⓔ, for insertion into the sockets ㉚ of the experimenting chamber, provided with a millimeter scale with a zero mark located at distance of approximately 110 mm from the cathode spot of the X-ray tube (measured horizontally!).

Experimenting table Ⓕ, which can be attached to the experimenting rail Ⓔ, for instance, for placing X-ray examination samples.

Magnetical adhesive suspension attachment Ⓖ, e.g. for fixing X-ray examination samples.

Stepped cuvette Ⓗ after filling with chalk powder, for instance, suitable for verification of attenuation as a function of the material thickness.

Zircon sheet Ⓘ, 0.05 mm thick; predominately allows X-radiation of the MoK_{α}-line to pass, attenuates the shorter-wave Bremsstrahlung and almost completely suppresses the MoK_{β}-line; suitable for investigation of the wavelength dependence of attenuation (K-edge) and for coarse monochromatization.

Copper foil Ⓚ, 0.07 mm thick, mainly for verification of the Compton effect and for investigation of the wavelength dependence of attenuation.

Aluminium scatter element Ⓛ, especially for verification of the Compton effect.

2 x 1.50 m stranded steel wire as hook-up cable for connection of the basic apparatus to the TY recorder (575 60).

2 cutter fuses each: 0.63 A slow-blow, 1.25 A slow-blow and 2 A slow-blow.

Dust cover for the basic apparatus.

2.1.2 Accessories for the 42 kV X-ray apparatus (554 90) with separate catalog numbers

Plate capacitors Ⓜ (554 91), see Figure 2, for insertion in the experimentation chamber of the basic apparatus.

The 3 plug-in feet comprise the electrical connections which can be externally wired through the sockets ㉛, ㉜ of the control panel.
A low voltage of 0...25 V AC, is routed in through ㉜ and is converted to a DC voltage of 0 ... 250 V DC by a transformer incorporated into the capacitor (see 5.2). When emitting radiation through air, the ionization current generated between the capacitor plates can be routed to a measuring amplifier through ㉛.
(Refer to 1.17 and the group of experiments 4.4 for dimensions, the current/voltage characteristics and dose rate).

Absorption accessory Ⓝ (554 92), see Figure 3, consisting of 2 cylindrical jacket segments with 7 slits each and a two-sided scale for attachment to the basic apparatus.
On one segment, 6 of the 7 slits are covered with aluminium layers having thicknesses of 0.5; 1.0; 1.5; 2.0; 2.5; 3.0 mm; this is used for quantitative

investigation of the dependence of attenuation on thickness of the material (refer to experiment 4.7.2). On the second segment, 6 of the 7 slits are provided with 0.5 mm thick layers of polystyrene, aluminium, iron, copper, zircon and silver with the atomic numbers 6; 13; 26; 29; 40; and 47; this serves to investigate the dependence of attenuation of the atomic number of the absorber (refer to experiment 4.7.3).
Both segments each contain one open slit for measuring the intensity of the unattenuated bundle of rays. The segments are inserted in the sample holder Ⓓ . With the ϑ_1 rotary knob ⑥ , the segments can be swivelled out of the control panel of the basic apparatus. The short pointer ⑭ of the basic apparatus indicates on the scale which sample is in the path of the beam.

Film holder Ⓟ and aperture Ⓞ (554 93), see Figure 4.
Aperture (Ø 1 mm) which can be fitted onto the slit diaphragm collimator Ⓐ for stopping out a fine bundle of X-rays (for instance, required for Laue and Debye Scherrer photographs; refer to experiments 4.6.1 and 4.6.4).

Film holder of transparent acrylic glass plate (mm x 165 mm) with base foot for attachment to the experimenting rail Ⓔ .

Singly packed flat X-ray films in a maximum format of 9 cm x 12 cm are held on the film holder by means of two included spring clips. A register mark for the center of the film and the layouts of two different, commercially available single-packing formats of the 9 cm x 12 cm X-ray film (OSRAY from AGFA-GEVAERT, commercially available) and the layout of the 38 mm x 35 mm film for immediate daylight development from Filmpack 2 (554 892) are printed on the film holder as aids to correct positioning.

2.2 Description of the 42 kV X-ray apparatus (554 90)

The X-ray apparatus is functionally subdivided into the following parts (see Figure 6):

- Safety circuit (see Section 2.2.1)
- Radiation generation chamber (see Section 2.2.2)
- Experimentation chamber (see Section 2.2.3)
- Control panel (see Section 2.2.4)
- Goniometer (2-fold swivel attachment with angular scale (see Section 2.2.5)
- Electrical power supply (not accessible to the user; not described).

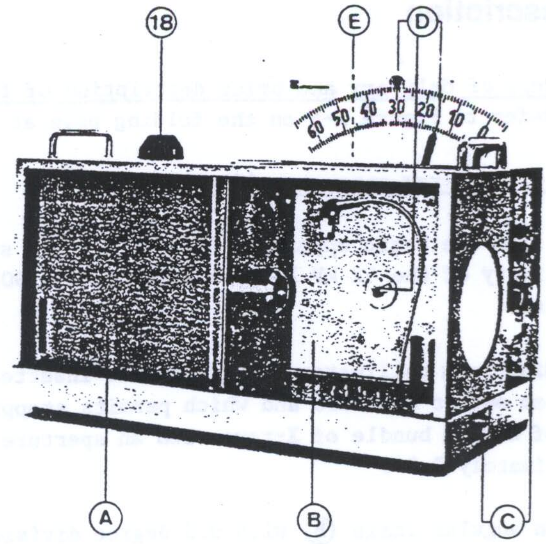


Figure 6

⑱ Large indicating lamp in the safety circuit
Ⓐ Radiation generation chamber
Ⓑ Experimenting chamber
Ⓒ Control panel
Ⓓ Shafts and pointers*) of the coaxial 2-fold swivel attachment for the counter tube holder Ⓒ and sample holder Ⓓ ; these comprise a goniometer in conjunction with the angular scale Ⓑ .
Ⓔ Housing for the electrical power supply and mechanical facilities

X-ray tube with spherical cooling head (554 94), see Figure 5.

The tube is not included in the scope of delivery of the basic X-ray unit (554 90). Please refer to Sections 1.4 and 2.2.2 for technical data and a description.

The "X-ray unit" equipment range also includes the following parts which are not illustrated:

- Lithium fluoride monocrystal (554 77) and sodium chloride monocrystal (554 78) for Bragg reflection
- Lithium fluoride crystal (554 87) and sodium chloride crystal (554 88) for Laue photography.

* When the apparatus is delivered, the pointers ⑭ and ⑮ are located within a recess in the housing and can be moved to their proper operating position by turning the knobs ⑤ and ⑥ to the left.

2.2.1 Safety circuit

the apparatus is used in accordance with specifications, the safety circuit guarantees completely reliable protection against high-voltage or radiation injury. It consists of the elements shown schematically in Figure 7.

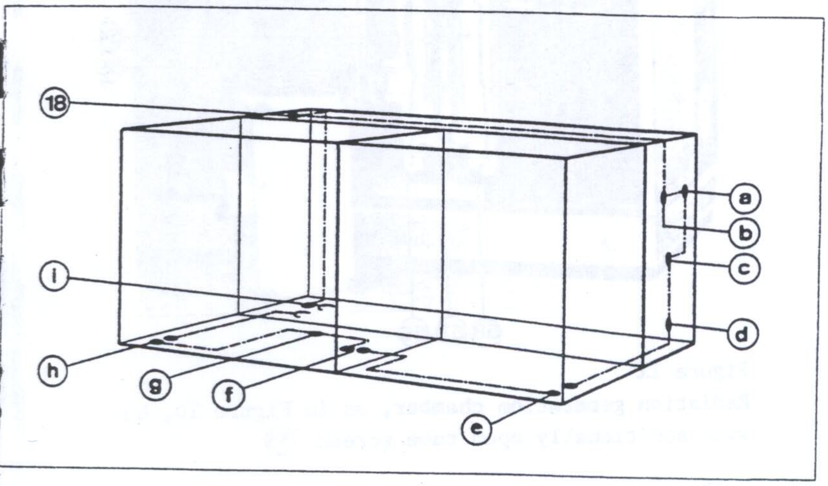


Figure 7

Elements of the safety circuit (schematic)

- (a) Pushbutton "high voltage off"
- (b) Pushbutton "high voltage on"
- (c) Stepped switch for high voltage
- (d) Time selector switch
- (e) Safety contacts, actuated by the closed glass sliding door (22)
- (f) Safety contacts, actuated by the X-ray tube screen
- (g) Bridge in the X-ray tube base
- (h) Safety contacts, actuated by the closed steel sliding door (21)
- (i) 1 A slow-blow fuse link
- (18) Large indicating lamp

2.2.2 Radiation generation chamber

X-ray tube: vacuum X-ray tube with directly heated ot cathode and molybdenum anode

Operating mode: half wave (half-wave rectification of the applied AC anode voltage by the tube itself)

Operating voltage: alternating voltage from the high-voltage transformer (Figures 10 and 11) adjustable from 21 kV_p to 42 kV_p in 8 steps of approximately 3 kV_p each (refer also to 1.4 and 1.5).

Cooling: The solid copper block of the anode transfers the dissipated heat of the anode to the cooling head; for this reason, this must not sit loosely in the anode thread when the X-ray tube is inserted. The tube and cooling head dissipate heat to an air flow produced by a fan. In this case, the tube screen serves as the flow duct.

Safety: The following serves the purpose of protection against high-voltage and radiation injury:
the tube screen consisting of plastic material containing lead,
the metal housing of the basic apparatus
lead glass window and lead glass sliding door of the experimentation chamber.

The socket for the X-ray tube is firmly fitted on the bracket plate (57). With a vertical adjustment :w (17), the radiation source can be externally raised and lowered without the need for access to the radiation generation chamber. Three locking screws (24) on the left-hand inside wall of the experimentation chamber fix the respective vertical adjustment (see Figure 12).

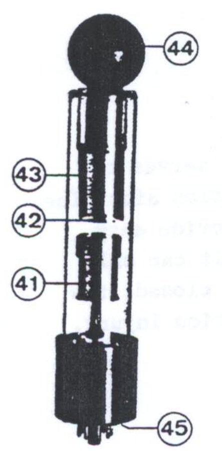


Figure 8

X-ray tube with cooling head

- (41) cathode system
- (42) molybdenum anode lining
- (43) anode block of copper
- (44) cooling head
- (45) base

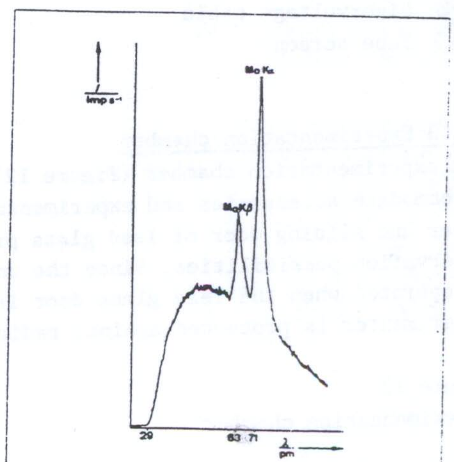
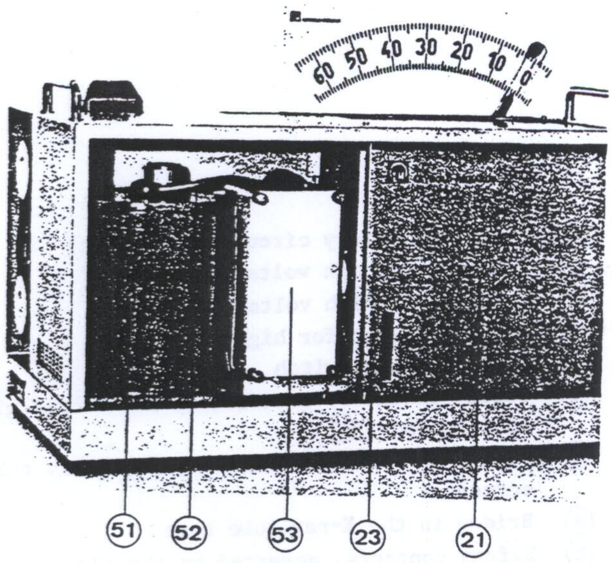


Figure 9

X-ray spectrum of the radiation source at maximum operating data (see also 1.4)



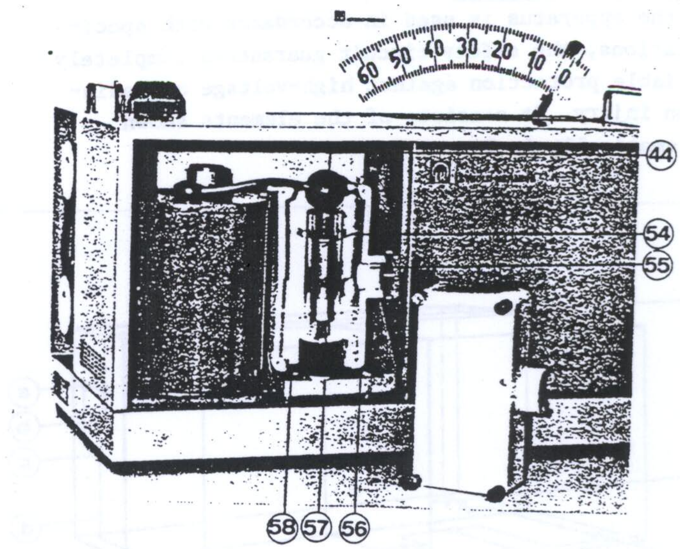


Figure 10
Radiation generation chamber with open metal sliding door (22)

(21) Metal sliding door
(23) Release pushbutton for the metal and lead glass sliding door (21) and (22)
(44) Cooling head of the X-ray tube
(51) High-voltage transformer
(52) High-voltage cable
(53) Tube screen

Figure 11
Radiation generation chamber, as in Figure 10, but with additionally open tube screen (53)

(54) X-ray tube
(53) Radiation outlet aperture
(56) Two contacts of the safety circuit which are actuated by the tube screen (53)
(57) Bracket plate as chassis of the radiation source; for vertical adjustment of the tube, this can be adjusted vertically with an externally accessible screw (17) after undoing 3 locking screws (24)
(58) Socket for X-ray tube

2.2.3 Experimentation chamber

The experimentation chamber (Figure 12) serves to accommodate accessories and experimentation aids. The cover and sliding door of lead glass provide easy observation possibilities. Since the unit can only be operated when the lead glass door is closed, the experimenter is protected against radiation injury.

Figure 12
Experimentation chamber

(17) Screw for vertical adjustment of the X-ray tube (can only be actuated when the screws (24) are undone; refer to 3.3).
(17) 1} Locking screws for the goniometer adjusted by
(17) 2} manufacturer (Adjusting screws! Do not undo!)
(22) Open lead glass door
(24) Locking screws for the bracket plate (57) with socket (58) for the X-ray tube (Figure 11); can only be actuated during vertical adjustment of the tube with screw (17) !
(26) Cable for counter tubes with socket for end-window counter (559 05 or 01)

(30) Sockets for plugging in experimentation equipment; an electrical voltage can be fed in from the control panel through the insulated pair of sockets; the remaining sockets are earthed by the housing.
(34) Luminescent screen of zinc cadmium sulphite, diameter 150 mm, located behind a round lead glass window.
Important: The luminescent screen must be protected against direct sunlight as otherwise it will become discolored.
(55) Radiation outlet aperture, Ø 42 mm, serving at the same time as the mount for the slit diaphragm collimator (A).
The aperture allows a cone of X-radiation to enter the experimentation chamber with an aperture angle of approximately 23°.
(62) Coaxial ϑ_1 and ϑ_2 shafts with attachments for securing the shaft with sample holder (D) and the counter tube holder (C) , e.g. for setting up an adjusted counter tube goniometer (refer to 2.2.5).

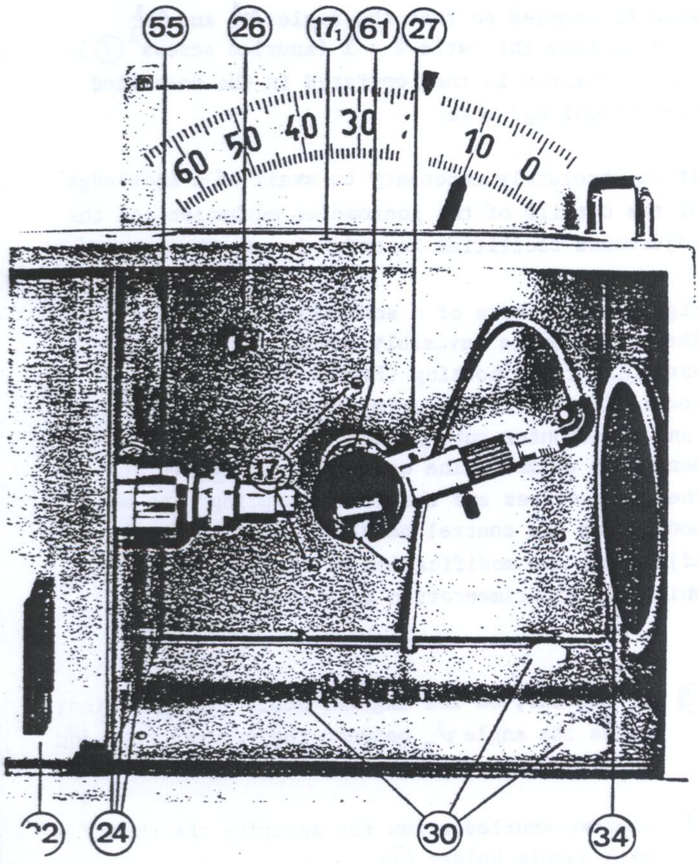


Figure 12

⑤ Rotary knob for ϑ_2-drive for setting the angle ϑ_2 between the counter tube and optical axis; with cable drum for winding up the stranded steel wire when the goniometer is connected to the TY-recorder (575 60) or a suitable motor.

⑥ Rotary knob for ϑ_1-drive for setting the angle ϑ_1 between the sample and optical axis.

⑦ Metallic knurled screw for so-called "2 ϑ-coupling"

⑧ Socket with 0.63 A slow-blow fuse link for the primary circuit of the high-voltage U ϟ

⑨ Pilot lamp "High voltage on"

⑩ "Off" pushbutton for the high-voltage U ϟ

⑪ Stepped switch for the high-voltage U ϟ
High voltage values adjustable in 8 steps of approximately 3 kV$_p$ each between approximately 21 kV$_p$ and approximately 42 kV$_p$

⑫ "On" pushbutton for the high-voltage U ϟ

⑬ Slide control for adjusting the emission current I_{EM}; adjustable from 0.05 mA to 1.0 mA

㉛ Coaxial socket for a current-sensitive measuring amplifier (532 91), especially for measuring the ionization current in the plate capacitor (554 91)

㉜ Input sockets for the low voltage for the plate capacitor (554 91) in which a 0-250 V DC transformer is incorporated.

㉝ Counter tube output coaxial socket for connection of the rate meter (575 52).

2.2.4 Control panel

The switching elements for the basic apparatus are provided on the control panel (see also Figure 1).

Figure 13
Control panel

① Toggle switch for the mains voltage; pilot lamp

② Pair of sockets for equivalence measurement of the high voltage U ϟ with demonstration moving coil instrument (531 86) or a different unit with a comparable internal resistance $R_i \geq 2.2\ k\Omega/V$; measurement range 30 V AC; $30\ V_{rms} \hat{=} 30\ kV_{rms} \hat{=} 30\ 2kV_p = 42.4\ kVp$

③ Pair of sockets for measuring the emission current I_{EM} with the demonstration multi-range meter (531 86) or a corresponding unit, measurement range 1 mA DC.

Time selector for preselection of the duty cycle of the high-voltage U ϟ

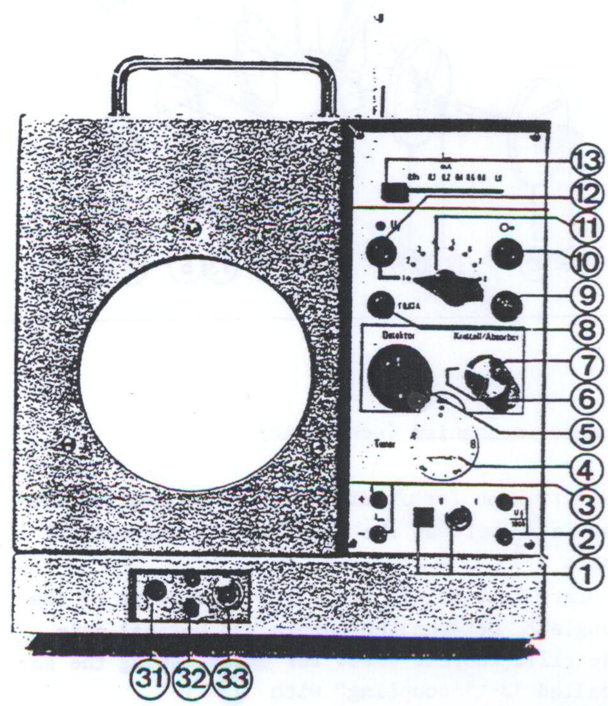


Figure 13

2.5 Goniometer (2-fold swivel attachment with [an]gular scale); see Figure 14 and Figure 1

In conjunction with the angular scale (C), a coaxial 2-fold swivel attachment for the sample holder (D) and counter tube holder (C) comprises a two pointer goniometer which is included in the scope of delivery of the basic apparatus. By means of the goniometer mechanism, it is possible to place samples (e.g. monocrystals, absorbers or scattering elements) centrally into a concentrated beam of X-rays stopped down by the slit diaphragm collimator (A) and to incline it by defined angles ϑ_1 with respect to the optical axis while at the same time swivelling the end-window counter tube with angles ϑ_2 with respect to the optical axis concentrically around the sample.

The counter tube holder and sample holder can be moved irrespective of each other; however, they can also be coupled so that the angles $\Delta\vartheta_2$ and $\Delta\vartheta_1$ covered have the ratio 2 : 1 (knurled screws (7)). The goniometer is then operated in the so-called "2-ϑ-coupling" mode.

It is absolutely necessary to avail of a knowledge of the details of the goniometer mechanism and the adjustment facilities in order to use the apparatus.

Figure 14 consists of a schematic diagram.
The mechanism is invisibly concealed in the rear part (E) of the housing (Figure 6); only the two coaxial shafts for securing the sample holder (D) and the counter tube holder (C) jut into the experimentation chamber. The control knobs (5), (6), (7) for the angle drives and the "2-ϑ-coupling" are accommodated on the control panel in order to facilitate adjustment and modification of the angles ϑ_1 and ϑ_2 while the experimentation chamber is closed.

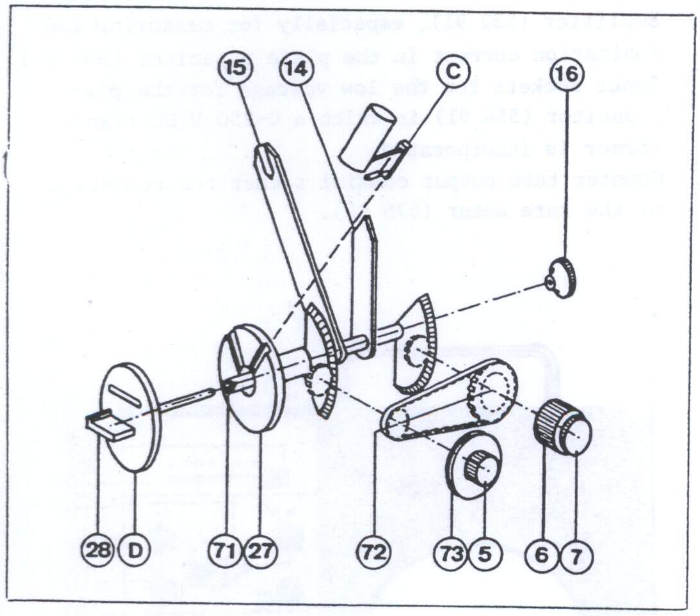


Figure 14

Goniometer mechanism (schematic)

(5) Rotary knob for ϑ_2-drive for adjustment of the angle ϑ_2 between the counter tube and optical axis

(6) Rotary knob for ϑ_1 drive for adjustment of the angle ϑ_1 between the sample and optical axis.

(7) Metallic knurled screw for establishing the so-called "2-ϑ-coupling" with (72):

ϑ_1-pointer; on the angular scale (B), this indicates the angle ϑ_1 between the sample and optical axis

(15) ϑ_2-pointer; on the angular scale (B), this indicates the angle ϑ_2 between the counter tube and optical axis.

(16) Captive knurled screw for securing the shaft with sample holder (D)

(27) Retaining disk on the ϑ_2-shaft designed as a hollow shaft, coaxially to (71) provided by two 60° mutually offset guide grooves for fitting the counter tube holder (C) (see also Figure 12).

(28) Rotary table which can be secured to the sample holder (D).

(71) ϑ_1-shaft, coaxial to (27), with front notch and bore for insertion of the shaft with the sample holder

(72) 2 : 1 angular transmission for coupling both ϑ-shafts so that $\Delta\vartheta_2 : \Delta\vartheta_1 = 2 : 1$

(73) Cable pulley on the ϑ_2-rotary knob for driving the goniometer with an external motor; suitable for connection of the TY recorder (575 60).

(C) Counter tube holder for the end-window counter (559 05 or 01) which can be optionally inserted in one of the two guide grooves of the retaining disk (27).

(D) Sample holder with securing attachment for the rotary table (28) and slot for accommodation of the absorber holder (from 554 92).

3 Handling

3.0 General notes

Every unit is carefully adjusted by Messrs. Leybold Heraeus, but is delivered without an X-ray tube. The X-ray tube (554 94) with molybdenum anode belonging to the unit is not included in its scope of delivery.

After insertion of the X-ray tube (or after replacement should this become necessary later; see Section 3.1), the unit is ready for use for all experiments which can be carried out without a slit diaphragm collimator (A).

Due to unavoidable production tolerances, the X-ray tube must be vertically adjusted once (see Section 3.3) for experiments with the slit diaphragm collimator (A) (refer to experiments 4.6 ff).

If the path rays has become maladjusted due to improper handling of the unit (e.g. inadmissible actuation of the adjustment screws (17.1), (17.2)), readjustment should be carried out only by the servicing agents of Messrs. Leybold Heraeus if the measures described in Sections 3.3, 3.4 and 3.5 are of no avaii.

3.1 Inserting the X-ray tube (554 94)

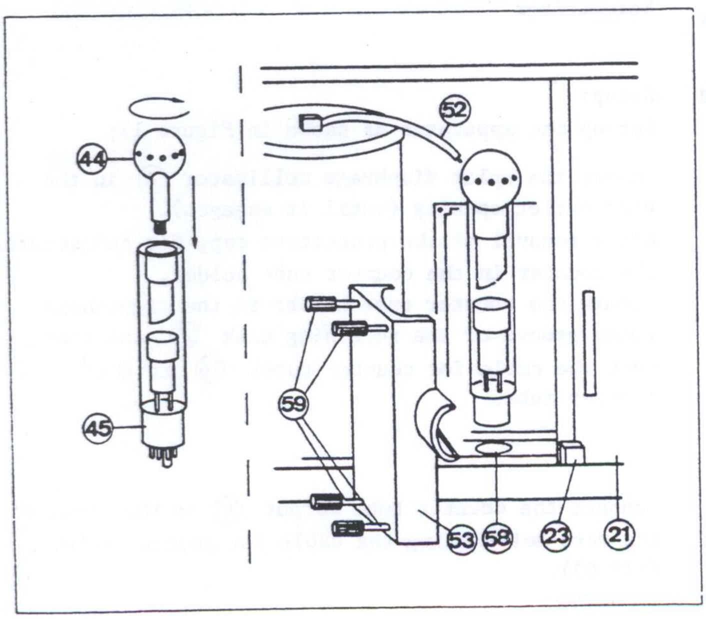


Figure 15 Inserting the X-ray tube

Open the steel sliding door (21) after operating the release pushbutton (23), undo the knurled screws (59) on the tube screen (53) and remove its front section.

Very thoroughly clean dust, fingerprints and persistent soiling from the interior and exterior of the tube screen (53), the tube socket (58), the jacketing of the high-voltage transformer, the high-voltage cable (52) and, above all, the X-ray tube and the cooling head (44) with a dry, lint-free cloth in order to avoid high-voltage arcing-over and creepage currents.

Do not use aggressive liquids (alcohol or solvents, etc.) for cleaning!

In order to remove persistent soiling (e.g grease), moisten a cloth with detergent; after treating parts in this way, carefully rub them dry with a dry cloth to ensure that no detergent residues remain.

Carefully screw the cooling head into the anode hole of the X-ray tube and tighten it slightly, at the same time making sure that, as far as possible, you touch the tube only with a cloth;
hold the tube by the cooling head (44) and the base (45) and, with the anode in the correct position (see Figure 15), firmly insert it into the socket (58) and plug the high-voltage cable (52) onto the cooling head (44);
once again screw the tube screw into place and close the chamber (the locking element must engage).

3.2 Activating X-radiation (see Figure 1)

Check that the mains voltage selector (20) is set to a value which agrees with the mains voltage in the room you are working; if necessary, change the setting accordingly (see Section 3.6).
Connect the apparatus to the mains socket with the mains cable and switch it on with switch (1); the pilot lamp lights up.
On the time selector (4), set the desired time or any time up to 2 hours (the high-voltage can otherwise not be activated because the time selector switch lies in the electrical safety circuit);
set the stepped switch (11) for the high-voltage U to Stage 1 and set the slide control (13) for the emission current I_{EM} to 0.05 mA (minimum value).

Activate the high-voltage with the "on" pushbutton (12).

Once all safety precautions have been taken:

a) X-ray tube correctly inserted and tube screen properly installed (see Section 3.1),
b) Sliding doors (21) and (22) internally locked (by engaging),
c) Time selector (4) operated,
d) Stepped switch (11) for high-voltage set to Stage 1,

...en the high-voltage pilot lamp (9) and the ...rthermore visible large indicating lamp (18) light up.

The X-ray tube emits a pulsating X-ray beam with a spectral distribution corresponding to the peak voltage 21 kV_p.

If the emission current I_{EM} and anode high-voltage $U_{\not{z}}$ are to be determined, connect two suitable measuring instruments such as demonstration multi-range meter (531 86) to the foreseen pair of sockets (3) and (2).

Measuring range for emission current I_{EM}: 1 mA DC
for high-voltage $U_{\not{z}}$: 30 V AC;
$R_i \geq 2.2\ k\Omega/V$.

The high-voltage is measured at a coil coupled inductively to the primary coil of the high-voltage transformer. Multiplied by $10^3 \cdot \sqrt{2}$, the average rms voltage indicated by the measuring instrument indicates the peak value of the high-voltage $U_{\not{z}}$:
$1\ V_{rms} \mathrel{\hat{=}} 10^3\ V_{rms} \mathrel{\hat{=}} 10^3 \cdot \sqrt{2}\ V_p$ (slight deviations from this mean value are possible, among other things due to production tolerances of the high-voltage transformer, differing operating temperatures and loads).

...er the high-voltage $U_{\not{z}}$ has been switched on, this ...an be increased with the stepped switch (11) to approximately 42 kV_p (Stage 8); approximately 30 V_{rms} are then indicated on the voltmeter.

The emission current I_{EM} can be continuously adjusted up to 1.0 mA with the slide control (13). An electronic regulation circuit limits and stabilizes the emission current to the set value.
In a dimmed room, a green luminescence caused by the emitted invisible X-radiation can now be observed on the fluorescent screen. The apparatus is now ready for use in experiments without slit diaphragm collimator (A).

3.3 Vertical adjustment of the X-ray tube

A fine concentrated beam of X-rays is required for various experiments. This is produced with the slit diaphragm collimator (A) (see Figure 1). The divergence of the beam of rays amounts to approximately 0.5°.

The longitudinal axis of the collimator defines the optical axis of the path of rays. Vertical adjustment of the X-ray tube means: moving the cathode spot of the tube to the optical axis (see Figure 16.1).

Figure 16.1

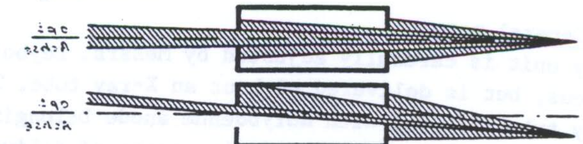


Figure 16.2

Path of X-rays through the slit diaphragm collimator when the cathode spot is in correct position (Figure 16.1) and when it is too low (Figure 16.2).

An indicator of the correct height of the X-ray tube is the intensity maximum of the beam of rays measured with the end-window counter tube. This maximum is found in a test setup as shown in Figure 17 by raising and lowering the X-ray tube.

Apparatus:

X-ray apparatus with split diaphragm collimator (A) and end-window counter (C)	554 90/94
End-window counter for beta and gamma rays	559 05 or 01
Cable for counter tubes, 100 cm	559 07
Rate meter	575 52
Demonstration multi-range meter	531 86
Additionally:	
Screwdriver	

Setup:
Set up the apparatus as shown in Figure 17;

Insert the split diaphragm collimator (A) in the beam outlet opening (until it engages).
After removal of the protective cap, fit and secure the counter in the counter tube holder, secure the counter tube holder in the right-hand guide groove of the retaining disk (27) and connect the cable for counter tubes (26) to the counter tube.

Connect the counter tube output (33) to the input of the rate meter using the cable for counter tubes (559 07).

Connect the demonstration multi-range meter to the output of the rate meter; measuring range of the instrument: 10 V DC.

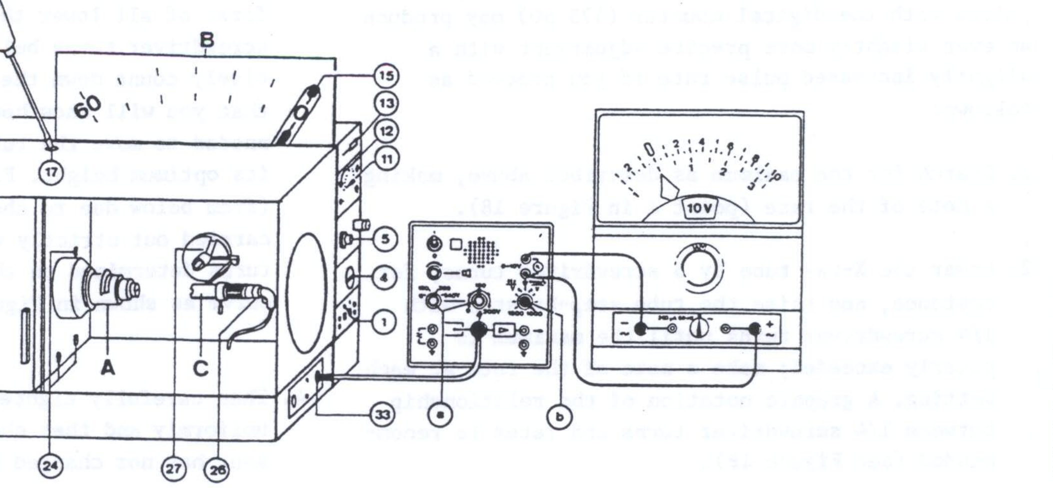


Figure 17

Make the following settings on the rate meter:
- At the pushbuttons (a) , set the counter tube voltage to approximately 460 V (on older counter tubes, it may be additionally necessary to redefine the counter tube plateau)
- Rate meter measuring range (Knob (b)): 1,000 imp./s per volt;
- Drive an audible signal generator as required.

Execution:

In order to measure the intensity, set the counter tube with the rotary knob (5) for ϑ/2-drive to 0° ± 0.2° on the angular scale (B) (pointers (15)) and switch on the counting apparatus (rate meter) and X-ray apparatus;
set the stepped switch (11) for the high-voltage U to Stage 1;
with the slide control (13) , preselect an emission current I_{EM} of 0.05 mA and set a time of approximately 15 minutes on the time selector switch (4) ; do not switch on the high-voltage yet.

Loosen the locking screws (24) just enough to move the tube fixture; completely lower the tube with fixture by turning the slotted screw (17) to the left.

Note:

With a view to well-defined adjustment, it is recommended always to set the required height only from the same side (best from below) due to the slight thread play of the screw (17) and the required friction in the tube fixture.

Close the lead glass sliding door (22) and activate the high voltage with pushbutton (12) .

For a rough adjustment of the intensity maximum, continuously raise the tube by slowly turning the screw (17) to the right until the intensity maximum is clearly exceeded.

For fine adjustment of the vertical position, lower the tube to just below the intensity maximum and then raise it to the now known maximum as carefully as possible;
carefully and uniformly tighten the three locking screws (24) and then check that the vertical adjustment has no longer changed.
When using this procedure, please remember that the indicated rates are constantly subject to slight, irregular fluctuations due to the pulse statistics.

Precision adjustment:

The previously described procedure leads to satisfactory axes adjustment of the cathode spot, thus making it possible to carry out all experiments requiring the slit diaphragm collimator.

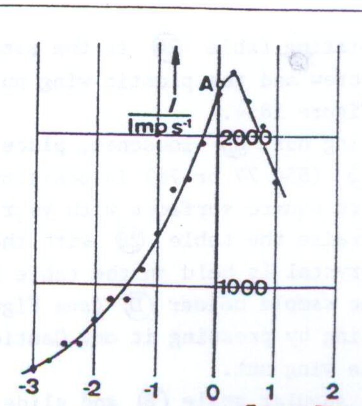


Figure 18

ep-by-step raising of the tube and counting the pulses with the digital counter (575 50) may produce an even slightly more precise adjustment with a slightly increased pulse rate if you proceed as follows:

1. Search for the maximum as described above, making a note of the rate (point A in Figure 18).

2. Lower the X-ray tube by 3 screwdriver turns, for instance, and raise the tube step-by-step with 1/4 screwdriver turns until the maximum is clearly exceeded; make a note of the rate at each setting. A graphic notation of the relationship between 1/4 screwdriver turns and rates is recommended (see Figure 18).

3. Once the maximum has been reliably recognized, first of all lower the tube once again (3 full screwdriver turns below the maximum) and also precisely count down the number of quarter turns so that you will know how many quarter turns are then nneded to move the tube from the lower position to its optimum height. Final adjustment of the tube (from below due to the thread play) can now be carried out strictly with the number of quarter turns determined on the basis of the table (or curve as shown in Figure 18).

4. Then carefully tighten the 3 locking screws (24) uniformly and then check that the vertical adjustment has not changed during this time.

3.4 Assembly of the goniometers for experiments with the Bragg configuration

Carry out installation in the following sequence (see Figures 19.1-19.5 and Figure 1).

a) Insert the slit diaphragm collimator (A) in the beam outlet opening (until it engages), see Figure 19.1.
After removal of the protective cap, insert the end-window counter tube (559 05 or 01) into the counter tube holder (C) and screw it tight.

c) Insert the counter tube holder with end-window counter tube in the right-hand guide groove of the retaining disk (27) and secure it as shown in Figure 19.2.

d) Connect the counter tube cable (26) to the counter tube as shown in Figure 19.3.

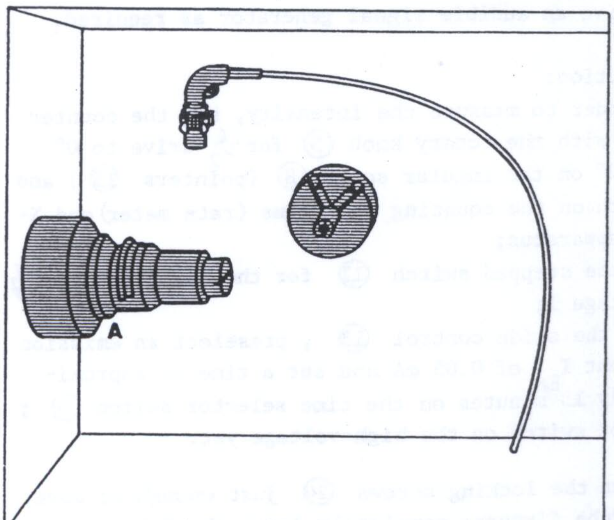
e) Insert the shaft of the sample holder (D) into the hole of the ϑ_1-axis and, by firmly tightening the captive knurled screw (16) on the rear of the X-ray apparatus, fix it in the experimentation chamber as shown in Figure 18.4 (the face notch in the ϑ_1-axis holds the sample holder in a defined position).

f) Fit the rotating table (28) to the sample holder with the screw and the plastic wing nut (83) as shown in Figure 18.4.

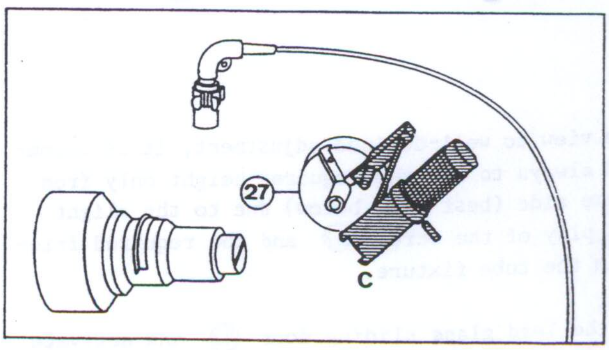
g) With the wing nut (83) loosened, place the monocrystal (82) (554 77 or 78) in position without touching its square surfaces with your fingers, carefully raise the table (28) with the crystal so that the crystal is held on the table by the stop (81) of the sample holder (D) (see Figure 19.5); avoid tilting by pressing it on! Cautiously tighten the wing nut.

h) Attach the angular scale (B) and slide it to the right until it moves no further.

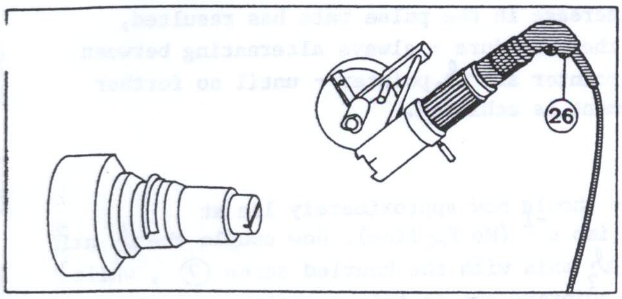
i) With the ϑ-coupling (screw (7)) undone, set the short ϑ_1-pointer (14) to 20°, for instance, with the rotary knob (6) and set the long ϑ_2-pointer (15) to to $2\vartheta_1 = 40°$ with the knob (5).



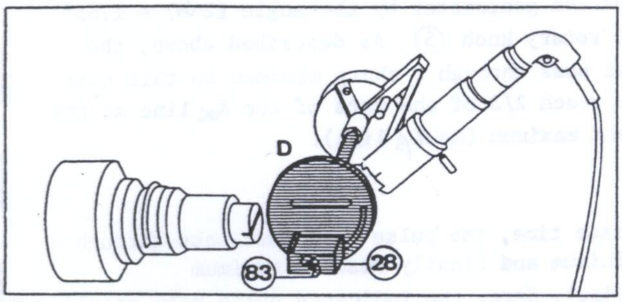
19.1



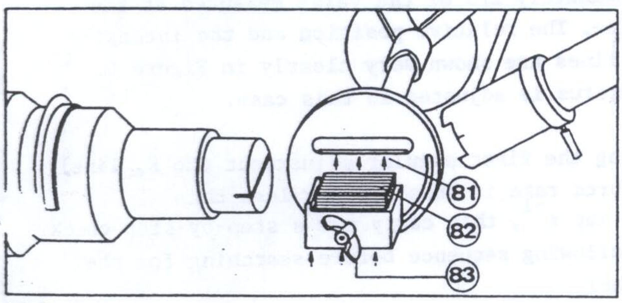
19.2



19.3



19.4



19.5

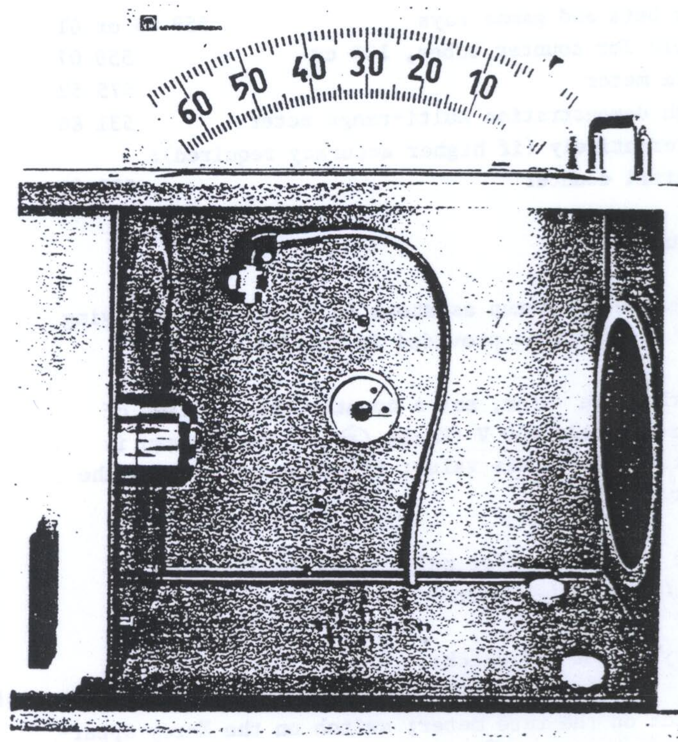
Important: Carry out angular setting very carefully; observe parallaxes!

Establish 2-ϑ-coupling by firmly tightening the screw ⑦ :

Important: Hold the rotary knob ⑥ when tightening the screw ⑦!

Figure 20

Experimentation chamber prepared for experiments with the counter tube goniometer



After connecting an apparatus for the power supply of the end-window counter tube (559 05 or 01) and for measurement of the pulses registered by the counter tube (e.g. rate meter 575 52, with digital counter 575 50 or the moving coil instrument 531 86) to the coaxial socket ㉝ , the counter tube goniometer is ready for operation.

3.5 Functional checking of the goniometer

The X-ray apparatus is delivered with the goniometer adjusted. Thus, within the framework of the scope of performance of the configuration, optimum conditions have been provided for angular adjustment and indication and for the registration of sufficiently high counting rates. If the X-ray apparatus (with vertically adjusted and hardened tube, see Sections (and 3.7) is operated properly, these can only be impaired by unavoidable production tolerances which can lead to differences between the indicated and set angles. Such deviations can be determined during functional checking of the counter tube goniometer. For this purpose, find the diffraction maxima of the first order of the molybdenum-K_α and -K_β lines in a Bragg configuration and ascertain whether or not the following criteria are fulfilled:

1) Separation of the lines Mo K_α and Mo K_β (see Figure 9),
2) Correct indication of the diffraction angles,
3) The expected amplitude of the pulse rate at the diffraction maximum of the first order (approximately 2×10^3 imp./s) for the Mo K_α line at maximum X-ray apparatus operating data.

paratus:

Slit diaphragm collimator Ⓐ)	
Angular scale Ⓑ)	from
Counter tube holder Ⓒ)	554 90
Sample holder Ⓓ with table ㉘)	
NaCl monocrystal (without yellow marking)	554 78
End-window counter tube for beta and gamma rays	559 05 or 01
Cable for counter tubes, 100 cm	559 07
Rate meter	575 52
with demonstration multi-range meter	531 86
Alternatively (if higher accuracy required):	
Digital counter	575 50

Setup:

Assemble the setup as shown in Figure 21, observing the instructions provided in Section 3.4:

On the rate meter, set a counter tube voltage of approximately 460 V (Knobs ⓐ if the plateau is guaranteed at this value; if necessary, record the characteristic).

Rate meter range for pulse counting (Knob ⓑ): 0 imp./s per Volt.

Carrying out the check:

Switch on the rate meter; switch on the X-ray apparatus with switch ①; on the time selector ④, preselect an operating time of ≥ 15 min; switch on the high-voltage with pushbutton ⑫.

Set the high-voltage U_p to Stage 8 (42 kV) with the stepped switch ⑪ and set the emission current I_{EM} to 1.0 mA with the slide control ⑬.

Set the coupled goniometer to the angles $\vartheta_1 = 7.25°$ and $\vartheta_2 = 14.5°$ with the rotary knob ⑤.
With this setting, a pulse rate of approximately 2×10^3 imp s^{-1} should be measured on the Mo K_α line.
If this is the case, slowly adjust the goniometer to smaller angles with the rotary knob ⑤, down to the position of the Mo K_β line ($\vartheta_2 = 12.85°$ and $\vartheta_1 = 6.43°$);
Observe the rate meter indication during movement.

If an increase in the pulse rate has resulted, repeat the procedure - always alternating between the ϑ_1-pointer and ϑ_2-pointer - until no further improvement is achieved.

The rate should now approximately lie at 2×10^3 imp s^{-1} (Mo K_α line). Now couple the ϑ_1 axis and the ϑ_2 axis with the knurled screw ⑦, while the two pointers are in this position, and slowly turn back the goniometer by the angle $(2\vartheta) = 1.65°$ with the rotary knob ⑤. As described above, the rate must pass through a sharp minimum in this case and must reach 2/3 of the rate of the K_α line at the subsequent maximum (Mo K_β line).

At the same time, the pulse rate must pass through a sharp minimum and finally reach a maximum (Mo K_β line). Here, the indicated pulse rate should be approximately 2/3 of the value measured at the Mo K_α line. The relative position and the intensity of both lines are shown very clearly in Figure 9. The apparatus is adjusted in this case.

If, during the first angular adjustment (Mo K_α line), the measured rate is considerably less than 2×10^3 imp s^{-1}, then carry out a step-by-step check in the following sequence before searching for the Mo K_β line:

a) Turn the NaCl crystal to the remaining 7 possible positions on the rotary table one after the other and measure the rate anew each time (mark the optimum position of the crystal by means of adhesive strips on the narrow side).
If, even in this case, a satisfactory rate can still not be measured,

b) search for the intensity maximum in the proximity of the set angles (7.25° and 14.5°):

After undoing the 2-ϑ-coupling (knurled screw ⑦), search for an intensity maximum in the proximity of the 7.25° setting by slowly moving the short ϑ_1-pointer to and fro with the rotary knob ⑥. Once such a maximum has been found, an improved maximum must be sought in the proximity of 14.5° by accordingly varying the ϑ_2 setting with the rotary knob ⑤.

If

1) there is a sharp separation of the lines Mo K_α and Mo K_β,
2) the angles at which the lines were found also do not deviate by more than ± 0.2° from the theoretical ϑ_1 or ϑ_2 value and if
3) the pulse rates at the determined optimum angle settings approximately reach the specified values, then the apparatus is adjusted well.

Angular deviations can be noted down and used, if necessary, for calculatory corrections (this is also possible at deviations greater than ± 0.2°).

A rate which is too low (even if the angular indications are satisfactory!) may be caused by:

a) an X-ray tube which is not hardened (see Section 3.7) or
b) inadequate vertical adjustment of the X-ray tube (see Section 3.3) or
c) maladjustment of the goniometer axes which cannot be remedied using the measures described in Sections 3.4 and 3.5 (inform our servicing agency in this case).

If there is no separation of the two lines Mo K_α and Mo K_β, then the goniometer is also maladjusted.

If only the angle indications no longer lie within the specified tolerance range, then it may be necessary to adjust the pointers; it is difficult to do this and, in this case, it is thus necessary to contact our servicing agency.

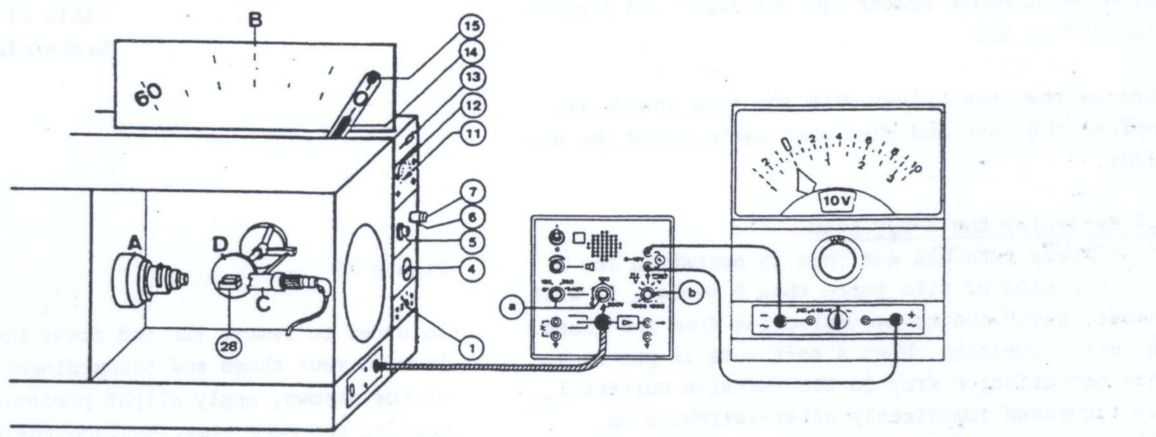


Figure 21

3.6 Conversion to mains voltages other than 220 V AC; replacing fuses

Important:
Remove the mains plug before replacing fuses!

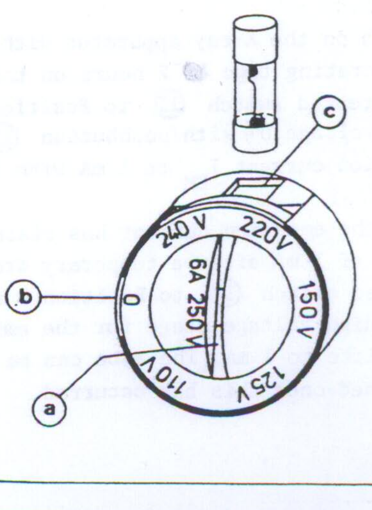


Figure 22

3.6.1
In order to convert to mains voltages other than 220 V AC, replace the 1.25 A slow-blow mains voltage fuse used for 220/240 V AC (2.0 A slow-blow for 110/125/150 V AC) in the mains voltage selector ⑳ as shown in Figure 1.

Replacement order numbers for fuses; 1.25 A, slow-blow: ET 69 816
2.0 A slow-blow: ET 69 808

order to replace the mains voltage fuse, insert a coin in the slot (a) and turn it until the "0" is next to the white marking (b) as shown in Figure 22. Catch hold of the fuse which has sprung out of the opening (c) in this position; slide a new fuse (chosen dimensioning in accordance with the mains voltage) into opening (c) and, using the tip of a ballpoint pen or similar, push it downwards while turning the coin in slot (a) at the same time; set the voltage selector so that the value specified on it for the local mains AC voltage lies next to the marking (b) .

3.6.2
Replace the 0.63 A slow-blow, high-voltage fuse in socket (8) as shown in Figure 1.

Replacement order number for the fuse 0.63 A slow-blow: ET 69 813

Unscrew the fuse holder with the fuse inside it, replace the fuse and then once again screw the cap tight.

3.7 Hardening the X-ray tube

If an X-ray tube has not been in operation for a longer period of time (more than 6 weeks), it will become "soft" due to gas molecules from the glass and metal surfaces. When a soft tube is put back into operation, a drop in the emission current I_{EM} is discovered immediately after switching on. This effect is particularly disadvantageous during quantitative experiments. If this is the case, then you should proceed as follows:

Connect a suitable measuring instrument to the pair of sockets (3) in order to measure the emission current I_{EM} (e.g., the demonstration multi-range meter 531 86) and put the X-ray apparatus into operation:

Switch on the X-ray apparatus with switch (1), set an operating time of 2 hours on the timer (4), set the stepped switch (11) to Position 1, switch on the high-voltage U↯ with pushbutton (12) and set the emission current I_{EM} to 1 mA with the slide control (13) .

Once the emission current has reached the first set value of 1 mA after a temporary drop, set the stepped switch (11) to Position 8 and now wait at this high-voltage stage for the emission current to stabilize to 1 mA. The tube can be considered as hardened once this has occurred.

3.8 Fault-finding

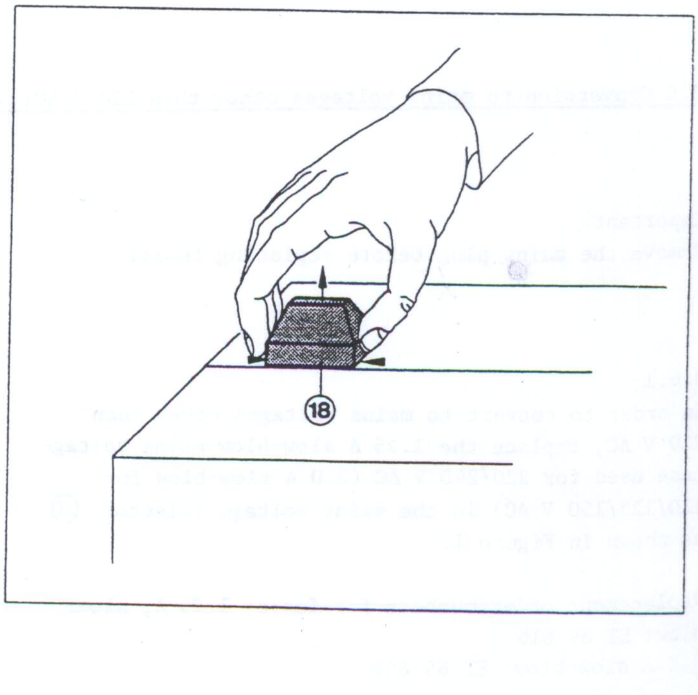
3.8.1 Activation problems

The main pilot lamp (1) does not light up after switching on:

Possible causes	Remedy
a) No mains voltage	Determine and eliminate the cause,
b) Fuse (20) defective	Replace the fuse (see Section 3.6)
c) Incandescent bulb in (1) defective	This does not impair operability of the apparatus; have the incandescent bulb replaced during the next visit of the servicing technician.

Figure 23

In order to remove the red cover hood, take hold of it with your thumb and index finger in the direction of the arrows, apply slight pressure and lift up the hood at the same time. Replace the double-ended tubular 12 V, 3 W incandescent bulb (replacement order No. ET 69 760).



The large indicating lamp (18) does not light up when the high-voltage is switched on with push-button (12):

Reason:
The safety circuit is not closed and one of the functional elements shown in Figure 7 is switched off. No high-voltage can be applied to the tube.

Possible causes	Remedy
a) Time selector (4) set to zero	Preselect a time
b) Stepped switch for high-voltage (11) not set to Stage 1	Set switch to Stage 1
c) Sliding doors (21) or (22) not locked	Close doors properly
d) Tube screen (53) (Figure 10) not installed or not properly fitted	Determine and eliminate the cause (see Section 3.1).
e) X-ray tube not installed or is not correctly fitted	Determine and eliminate the cause (see Section 3.1)
f) Incandescent bulb in (18) defective	Replace as shown in Figure 23
g) Malfunctions other than a)-f)	Inform the servicing agency. The 1 A slow-blow fuse permanently installed in the interior of the apparatus ((i) in Figure 7) must not be replaced by the user since, when it blows, it indicates a defect which, in certain circumstances, may be a grave one.

3. The high-voltage pilot lamp (9) does not light up although the large indicating lamp (18) is bright.

Important:
The high-voltage may still be applied to the X-ray tube despite a faulty indication of the lamp (9)!

Possible causes	Remedy
a) Fuse in (8) defective	Replace (see Section 3.6)
b) Incandescent bulb in (9) defective	This does not impair operability of the apparatus; have the incandescent bulb replaced during the next visit of our servicing technician.
c) Malfunctions other than a) and b)	Inform our servicing agency

3.8.2 Loud crackling in the ray generation chamber

Sometimes loud crackling occurs in the ray generation chamber during operation of the X-ray apparatus with a very high voltage. This can be ascribed to high-voltage arcing-over in the area of the high-voltage cable due to soiling (e.g. due to slight accumulation of dust). This effect is not only an annoying accompanying phenomenon during operation of the apparatus, but also considerably stresses the electrical systems. Immediate elimination of the cause is therefore necessary.

First of all, carefully clean the coverplate of the transformer, the high-voltage cable and the cooling head of the X-ray tube with a clean, lint-free cloth soaked in alcohol. In certain circumstances, it may be necessary to clean the X-ray tube if the X-ray apparatus is stored in dusty rooms; however, this should not be done unless the first measure produces no considerable improvement because, after removal of the X-ray tube, readjustment cannot be avoided in most cases (see Section 3.3).

3.8.3 Unsatisfactory experimental results:

1. During screen investigations (high-voltage Stage 8!):

Possible causes	Remedy
a) Soft X-ray tube (emission current has dropped)	Reharden the X-ray tube (see Section 3.7)
b) X-ray tube too old (after more than 300 hours of operation)	Replace the X-ray tube (see Section 3.1)

2. During plateau determination in a capacitor experiment:

Possible causes	Remedy
a) Soft X-ray tube (emission current has dropped)	Reharden the X-ray tube (see Section 3.7)
b) X-ray tube too old (after more than 300 hours of operation)	Replace the X-ray tube (see Section 3.1).
c) Voltage transformer in the capacitor defective	Carry out a check in accordance with experiment 4.4.1; if defective, send in the capacitor for repair

3. In the case of Laue or Debye-Scherrer photographs:

Possible causes	Remedy
a) Soft X-ray tube (emission current has dropped)	Reharden the X-ray tube (see Section 3.7)
b) X-ray tube too old (after more than 300 hours of operation)	Replace the X-ray tube (see Section 3.1)
c) Height of the X-ray tube maladjusted	Adjust the height of the X-ray tube (see Section 3.3)

4. During the examination of spectograms in a Bragg configuration:

In a Bragg configuration, the Mo K_α and Mo K_β lines are not correctly resolved with the goniometer or measured at incorrect diffraction angles.

Possible causes	Remedy
Path of rays maladjusted (e.g. X-ray tube not vertically adjusted) or goniometer maladjusted	If necessary, vertically adjust the X-ray tube (see Section 3.3) and carry out a functional check of the goniometer (see Section 3.5); If the apparatus is otherwise maladjusted, inform our servicing agency

5. During counter tube measurements

Too low or irreproducibly fluctuating pulse rates are measured with the counting tube:

Possible causes	Remedy
a) Soft X-ray tube (emission current has dropped)	Reharden the X-ray tube (see Section 3.7)
b) X-ray tube too old (after more than 300 hours of operation)	Replace the X-ray tube (see Section 3.1)
c) X-ray tube not vertically adjusted	Vertically adjust the X-ray tube (see Section 3.3)
d) Fault in the counting apparatus	Pursue the fault further there

Important:
Should malfunctions or faults occur which cannot be remedied with the measures listed in Section 3.8, please make use of our servicing agency in all cases!